

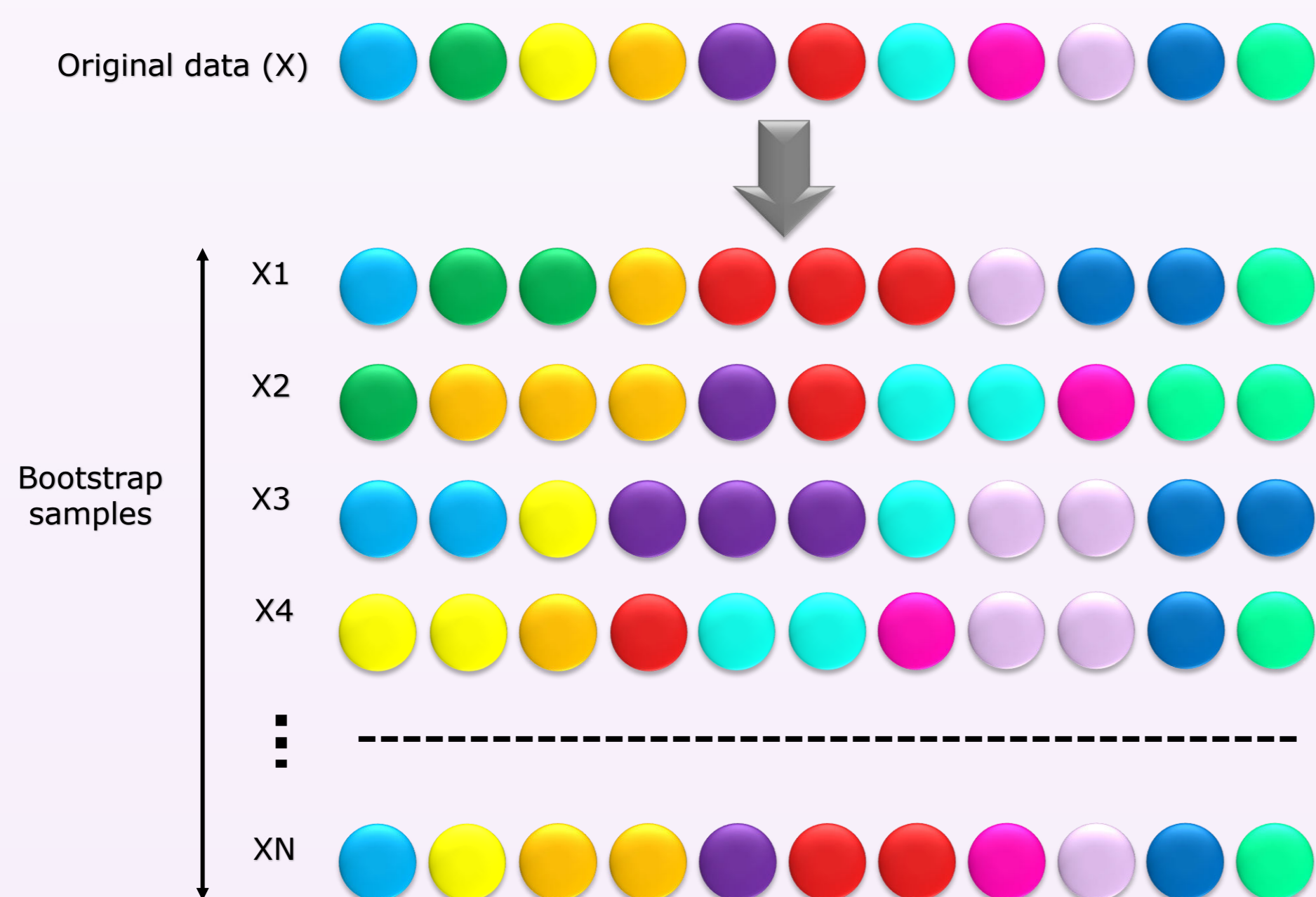
# Bootstrap-boosted statistical analysis

Statistical models of multiple comparisons for small samples using the bootstrap method in the analysis of selected epidemiological factors in cardiovascular diseases.

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## Introduction

Bootstrap is a method first proposed by Bradley Efron and involves random sampling with replacement. A bootstrap sample ( $X^*$ ) is created from the original data by drawing with return. As a result, the elements selected from  $X$  may repeat many times, and some of them may not appear in the drawn group [1,2]. In the original version of bootstrap,  $n$  elements are drawn, which means that the bootstrap sample has the same number of elements as the original one.



Here I present what bootstrapping is all about and the practical use of this method when analyzing real data that has been published: Karolczak K, Konieczna L, Soltysik B, Kostka T, Witas PJ, Kostanek J, Baczek T, Watala C. Plasma Concentration of Cortisol Negatively Associates with Platelet Reactivity in Older Subjects. *Int J Mol Sci.* 2022 Dec 31;24(1):717. doi: 10.3390/ijms24010717. PMID: 36614157; PMCID: PMC9820908.

## Materials and Methods

### Study population

The cortisol data came from a group of 128 volunteers (63 females and 65 males) selected from a population of 300 study participants.

### Software

Simulations were performed using Statistica 13 (StatSoft), R packages and self-prepared software in R.

### Statistical Analysis

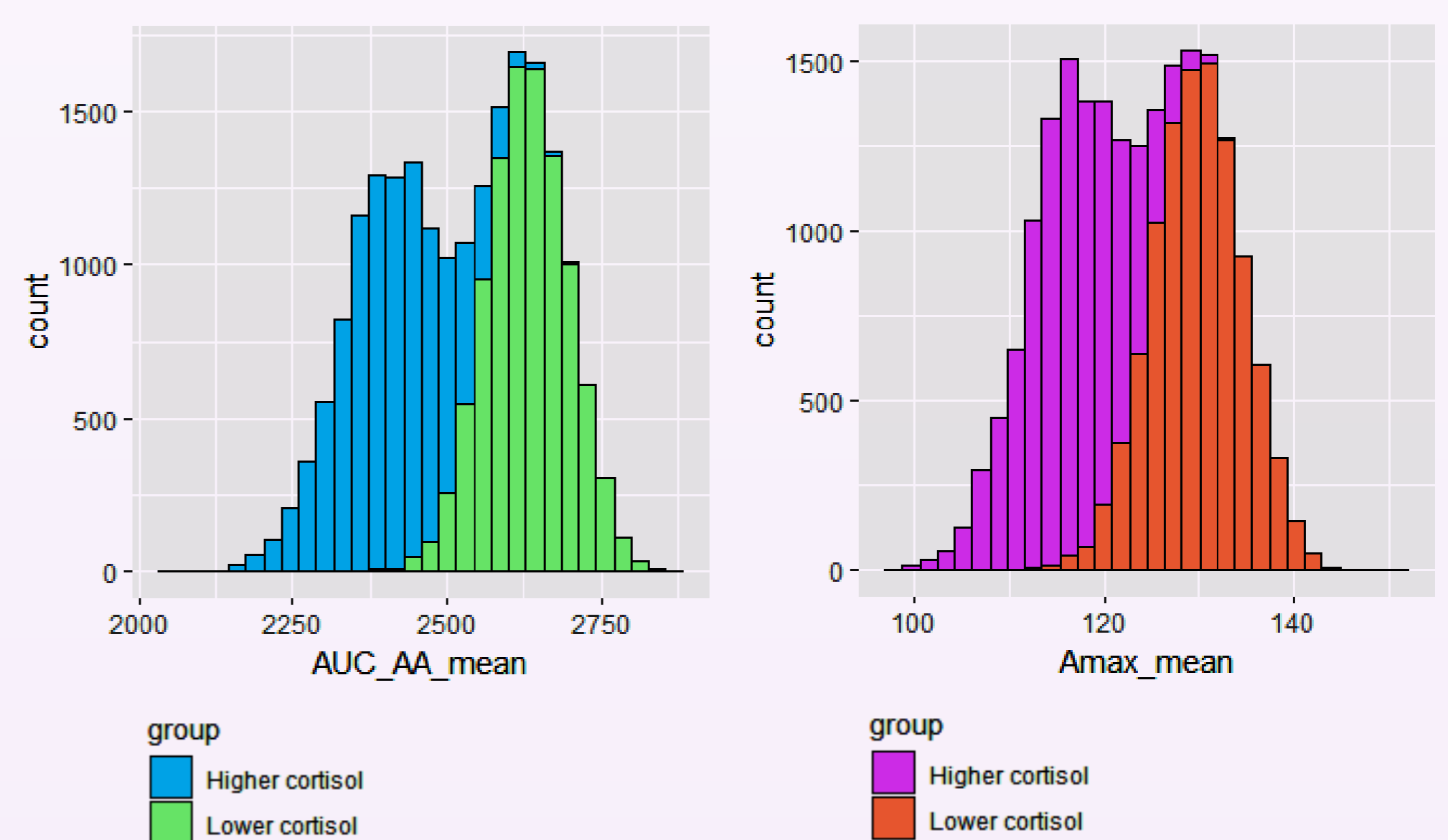
The bootstrap-boosted ANCOVA was used for the comparisons. Furthermore, the bootstrap-boosted partial correlation and Spearman's ranks correlation were used to evaluate the associations between variables. Resampling was calculated in two variants: for a group of 128 patients and with an adjustment to 300 patients which was the size of the overall group enrolled in the study. Each bootstrap-boosted analysis was performed in 10,000 iterations.

## Results

Reactivity of blood platelets was measured in response to arachidonic acid (AA) and recorded as an area under aggregation curve (AUC) or a maximal aggregation (Amax).

### Histograms of bootstrap data

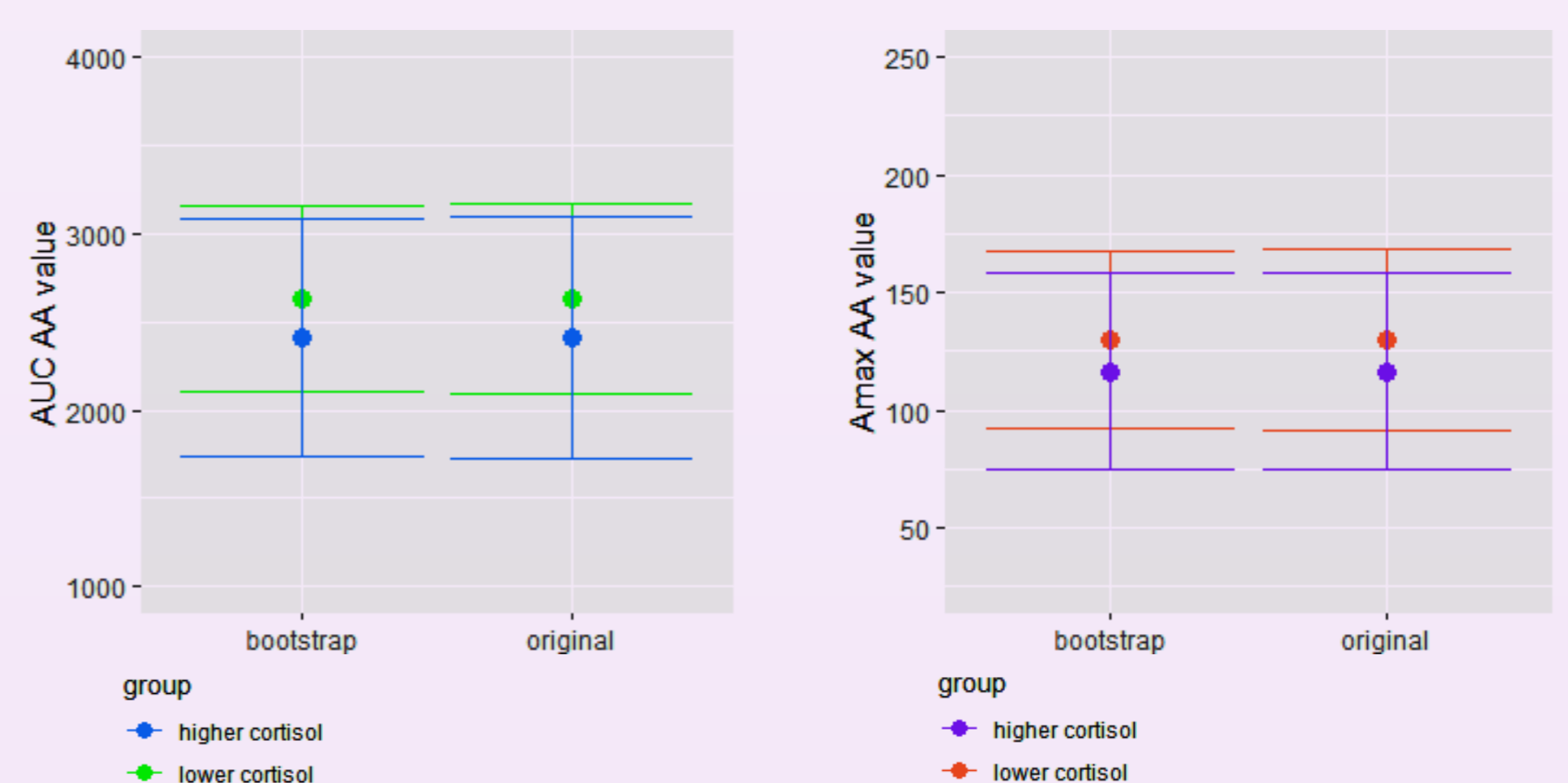
The bootstrap distribution of platelet reactivity from each resample. The distribution is shown for two groups: lower and higher cortisol).



### Comparison of averages in original and bootstrap data

Platelet reactivity in relation to plasma cortisol concentration.

	Lower Cortisol Concentration (n = 64)	Higher Cortisol Concentration (n = 64)
	AUC AA	AUC AA
original data mean	2630,67 ± 534,75	2410,49 ± 683,27
bootstrap data mean	2630,05 ± 527,84	2410,20 ± 673,86



## Scientific achievements & further research

The methodology I propose as part of my doctoral dissertation has managed to serve to develop three publications that I co-authored:

- ❖ Karolczak K, Guligowska A, Kostanek J, Soltysik B, Kostka T, Watala C. The amino acid content in the daily diet of seniors negatively correlates with the degree of platelet aggregation in a sex- and agonist-specific manner. *Aging (Albany NY)*. 2022 Aug 19;14(18):7240-7262. doi: 10.18632/aging.204229. Epub 2022 Aug 19. PMID: 35985680; PMCID: PMC9550244.
- ❖ Karolczak, K.; Kostanek, J.; Soltysik, B.; Konieczna, L.; Baczek, T.; Kostka, T.; Watala, C. Relationships between Plasma Concentrations of Testosterone and Dihydrotestosterone and Geriatric Depression Scale Scores in Men and Women Aged 60–65 Years—A Multivariate Approach with the Use of Quade's Test. *Int. J. Environ. Res. Public Health* 2022, 19, 12507. <https://doi.org/10.3390/ijerph191912507>
- ❖ Karolczak, K.; Konieczna, L.; Soltysik, B.; Kostka, T.; Witas, P.J.; Kostanek, J.; Baczek, T.; Watala, C. Plasma Concentration of Cortisol Negatively Associates with Platelet Reactivity in Older Subjects. *Int. J. Mol. Sci.* 2023, 24, 717. <https://doi.org/10.3390/ijms24010717>

Another publication is currently being prepared for review.

In the next stage of my research, I plan to use the bootstrap method to develop an effective way to solve the problem of multiple comparisons among small samples.

## REFERENCES

- [1] B. Efron; Bootstrap Methods: Another Look at the Jackknife. *Ann. Statist.* 7 (1) 1 - 26, January, 1979. <https://doi.org/10.1214/aos/1176344552>  
 [2] DS Moore, GP McCabe, WM Duckworth, SL Sclove; *The Practice of Business Statistics Companion Chapter 18: Bootstrap Methods and Permutation Tests*; W. H. Freeman, 2003; ISBN:0716757265, 9780716757269